2004 GALVESTON BAY INVASIVE SPECIES RISK ASSESSMENT
INVASIVE SPECIES SUMMARY
Created by: Environmental Institute of Houston, University of Houston-Clear Lake
and the Houston Advanced Research Center

Common Name: Zebra Mussel

Latin Name: *Dressiena polymorpha*

Category: Aquatic Animal

Place of Origin: "Native Distribution: Zebra mussels originated in the Balkans, Poland, and the former Soviet Union. In 1769, Pallas first described populations of this species from the Caspian Sea and Ural River." http://nas.er.usgs.gov/zebra.mussel/docs/sp_account.html (Accessed 10 March 2003).

Place of Introduction: "In North America, zebra mussels were first identified in Lake St. Clair, near Detroit in 1988 (Hebert et al., 1988). Accidental introduction most likely occurred by release of larvae contained in ship ballast water (Hebert et al., 1989). The zebra mussel's high fecundity, passively dispersed veliger larval stage, and its ability to attach by byssal threads to hard surfaces such as boat hulls, nets, buoys, and other floating debris allowed it to spread rapidly throughout Lake Erie, the western end of Lake Ontario and the St. Lawrence River (Ram and McMahon, 1996). Subsequently, the zebra mussel has migrated to the Hudson River, upper New York state and west to the Mississippi River.

"The mussel is now found in the Mississippi river from St. Paul Minnesota to the mouth of the river in Louisiana (Ram and McMahon, 1996). Zebra mussel also now infest most of the major Mississippi River tributaries, including the Ohio, Tennessee, Cumberland, and Arkansas Rivers (Griffiths et al., 1991; Ram et al., 1992; McMahon, 1992; O'Neill and Dextrase, 1994). By the end of 1995, zebra mussels had invaded waters in 20 of the 38 U.S. states east of the Rocky Mountains, as well as the Canadian provinces of Ontario and Quebec (Ram and McMahon, 1996). Human-mediated vectors may be responsible for the zebra mussel dispersal to isolated inland bodies of water in Connecticut, Illinois, Indiana, Michigan, New York, Ohio, Vermont, and Wisconsin." http://www.gsmfc.org/nis/nis/Dreissena_polymorpha.html (Accessed 10 March 2003).

"Zebra mussels are native to the Caspian and Black Seas. They are now established in the UK, Western Europe, Canada and the USA. They compete with zooplankton for food, thus affecting natural food webs. They also interfere with the ecological functions of native molluscs and cause great economic damage." http://www.issg.org/database/species/ecology.asp?si=50&fr=1&sts= (Accessed 10 March 2003).

Method of Introduction: It is highly likely that the presence of zebra mussels in the Great Lakes was a result of a ballast water introduction. Its rapid dispersal throughout the Great Lakes and major river systems was due to its ability to attach to boats navigating these lakes and rivers. Its rapid range expansion into connected waterways was probably due to barge traffic where it is theorized that attached mussels were scraped or fell off during routine navigation. Overland dispersal is also a possibility for aiding zebra mussel range expansion. Many small lakes in proximity of the Great Lakes, unconnected by waterways but accessed by undividuals trailering their boats from infested waters, have populations of zebra mussels living in them. At least eight trailered boats crossing into California had zebra mussels attached to their hulls or in motor compartments; all were found during inspections at the agricultural inspection stations. Under cool, humid conditions, zebra mussels can stay alive for several days out of water. http://nas.er.usgs.gov/zebra.mussel/docs/sp_account.html (Accessed 10 March 2003).

Date of Introduction: 1988

Life History: "Distribution**:** Prior to the 19th century, zebra mussel ranged the Black, Caspian, and Azov seas (Stanczykowska, 1977). Between 1800 and 1900, the zebra mussel more than doubled its range in Europe (Schloesser, 1995). It is now found throughout most of Europe and extending east into the western Asia and south into Turkey (Mackie et al, 1989). It remains absent from Spain, the Italian Peninsula, most of Scandinavia, Ireland, and Scotland. Human-mediated dispersal mechanisms (e.g., artificial waterways, ships, fishing activities, amphibious planes and recreational equipment) are the probable means for such rapid spread of the species (Kinzelbach, 1992; Morton, 1993).

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"Current Status of this Species in the Gulf of Mexico Ecosystem: Zebra mussels are currently found in the Lower Mississippi river and its distributary, the Atchafalaya. They have also been found at several locations in the Gulf Intercoastal Waterway between New Orleans and Morgan City, Louisiana. Despite ongoing connection to infested waters of the Tennessee River, zebra mussels have not yet been found in the Tombigbee system. Because zebra mussels are primarily freshwater organisms, their potential distribution in the Gulf of Mexico region will likely be limited to suitable fresh waters and slightly brackish waters." http://www.gsmfc.org/nis/nis/Dreissena_polymorpha.html (Accessed 10 March 2003).

"Lifecycle Stages
Fertilized egg hatches into trocophore (40-60 microns, 1-2 days), several stages of free-swimming planktonic veliger lasting 8-180 days (or longer in cold water), then at 350 micron size the larvae settle as plantigrade mussels, attach to substrate as juveniles, and may mature within the first year of life under optimal conditions; maturity in the second year is more usual. Zebra mussels live 3-5 years." http://www.issg.org/database/species/ecology.asp?si=50&fr=1&sts= (Accessed 10 March 2003).

"Life History: Females generally reproduce in their second year. Eggs are expelled by the females and fertilized outside the body by the males; this process usually occurs in the spring or summer, depending on water temperature. Optimal temper ature for spawning is 14-16 oC. Over 40,000 eggs can be laid in a reproductive cycle and up to one million in a spawning season. Spawning may last longer in waters that are warm throughout the year. After the eggs are fertilized, the larvae (veligers) emerge within 3 to 5 days and are free-swimming for up to a month. Optimal temperature for larval development is 20-22 oC. Dispersal of larvae is normally passive by being carried downstream with the flow. The larvae begin their juvenile stage by settling to the bottom where they crawl about on the bottom by means of a foot, searching for suitable substratum. They then attach themselves to it by means of a byssus, an organ outside the body near the foot consisting of many threads. Although the juveniles prefer a hard or rocky substrate, they have been known to attach to vegetation. As adults, they have a difficult time staying attached when water velocities exceed two meters per second. Zebra mussels are filter feeders having both inhalant and exhalant siphons. They are capable of filtering about one liter of water per day while feeding primarily on algae.

Zebra mussels get their name from the striped pattern of their shells. However, the pattern has been seen to vary greatly to where there are no stripes, only dark or light colored shells. Zebra mussels can grow to a maximum length of about 50 mm (5-10 mm in the first year) and live four to five years. They inhabit fresh water, usually at depths of two to seven meters. Even though zebra mussels are freshwater animals, they have recently been found living in brackish water with salinity levels of one to two parts per thousand. Calcium is an important nutrient for survival with an optimal range of 25 -125 parts per million. Other environmental factors such as water temperature, pH, and dissolved oxygen also play a critical role in survival. Water temperatures of 17-25 oC are optimal, above 31 oC is usually lethal. Zebra mussels are rarely found in waters with a pH less than 7.4 or greater than 8.5. Well oxygenated waters, 8 to 10 parts per million, are preferred." http://nas.er.usgs.gov/zebra.mussel/docs/sp_account.html (Accessed 10 March 2003).

Growth/Size:

Reproductive Season: In temperate environments spawning takes place during the summer and can extend from 2-8 months, but typically 2-5 months, depending on biotic and abiotic factors including temperature and food availability (McMahon, 1990; Mcakie and Schloesser, 1996). Populations in the Lower Mississippi River spawn primarily in May and then not again until the fall. However, because of spawning of upstream populations, veligers are found in the river and its distributaries from the beginning of May through the end of October (Y. Allen, unpublished data).

Maximum Size: *Dreissena polymorpha* exhibit quite variable shell size but, in North America the adult shell length at sexual maturity is generally 8-10 mm (Ackerman et al., 1994). This is larger than its European counter-part where adult shell size is from 3-5 cm in length (Mackie et al, 1989). http://www.gsmfc.org/nis/nis/Dreissena_polymorpha.html (Accessed 10 March 2003).

"Fecundity: In North America, Zebra mussels become sexually mature in their first year (8 to 10 mm shell length) and have exceedingly high fecundities (reproduction rate); females can produce from 30,000 to 1,610,000 eggs/female/year (Mackie et al., 1989; Borcherding, 1992)." http://www.gsmfc.org/nis/nis/Dreissena_polymorpha.html (Accessed 10 March 2003).

"Reproductive Mode
Zebra mussels are dioecious and fertilize externally; larvae are planktonic for several weeks before settling and attaching to substrate

Reproductive Output
Estimated at up to 1.5 million eggs per female per year; survival to adult stage may be less than 1%."
http://www.issg.org/database/species/ecology.asp?si=50&fr=1&sts= (Accessed 10 March 2003).

"Size: Up to 50 mm" http://nas.er.usgs.gov/zebra.mussel/docs/sp_account.html (Accessed 10 March 2003).

Feeding Habits/Diet:
Nutrition or Nutrient Requirements:
Filter a wide range of size particles, but select algae and zooplankton between 15-40 microns. Larval stages feed on bacteria. http://www.issg.org/database/species/ecology.asp?si=50&fr=1&sts=

Habitat: "Zebra mussel populations are most abundant where waters are hard (30-50 mg Ca L^{-1}), moderately eutrophic, and temperate (maximum summer temperatures less than 28°C). Although also found in waters with suboptimal conditions, however, growth and reproductive success are typically lower and mortality rates higher.

Salinity tolerance: *D. polymorpha* can tolerate slightly brackish water, however, they are extremely sensitive to rapid fluctuations in salinity that are commonly observed in areas under strong tidal influence. In the northern Gulf of Mexico, where tidal fluctuations are not great, zebra mussels are found to invade areas with salinities up to 12 ppt. They appear unable to tolerate salinities above 12 ppt for any extended period." http://www.gsmfc.org/nis/nis/Dreissena_polymorpha.html

Attitude (aggressive, etc.):
"The zebra mussel's high fecundity, passively dispersed veliger larval stage, and its ability to attach by byssal threads to hard surfaces such as boat hulls, nets, buoys, and other floating debris allowed it to spread rapidly throughout Lake Erie, the western end of Lake Ontario and the St. Lawrence River (Ram and McMahon, 1996)."
http://www.gsmfc.org/nis/nis/Dreissena_polymorpha.html (Accessed 10 March 2003).

"This species has been nominated as among 100 of the "World's Worst" invader"
http://www.issg.org/database/species/ecology.asp?si=50&fr=1&sts= (Accessed 10 March 2003).

Physical Description:
"Distinguishing Features: The prominent dark and light banding pattern on the shell, is the most obvious characteristic of the zebra mussel. Its specific name, "polymorpha", derives from the species many variations in shell color, pattern and shell shape. Shell color morphs have been reported by Biochino (1989; 1990) and Smirnova et al, (1993) to break down into 6 basic patterns, and then categorized based on the zigzag patterns, stripe width and location and type of zigzag interruptions in each stripe. However, the usefulness of this categorization for North American zebra mussels is questionable (Y. C. Allen, pers. observ.). The outer covering of the shell (the periostracum) is generally well polished, light tan in color with a distinct series of broad, dark, transverse color bands which may be either smooth or zigzag in shape. With-in a population, individual shell colors may range from very light colored without discernable dark banding to those that are darkly-pigmented overall, obliterating all banding.
The shape of Zebra mussel shells is generally triagonal or triangular with sharply pointed umbos (the hinge end). Underlying the umbos, the hinge plate or myophore plate is broad and well developed with no pseudocardinal or lateral teeth. The valves are joined by a proteinaceous ligament located posterior to the umbos. The valves are quite inflated posteriorly tapering to a more flattened profile along the ventral and anterior margins; an acute ridge runs from the umbos to the posterior point of the ventral margin forming a distinctive "shoulder". The mussel attaches itself to hard surfaces by byssal threads which are secreted from a byssal gland just posterior to the foot. The byssal threads emerge from the between the valves through a byssal notch along the posterior margin. This byssal hold-fast distinguishes the zebra mussel from all other similar-sized or larger North American freshwater bivalves (McMahon, 1990)." http://www.gsmfc.org/nis/nis/Dreissena_polymorpha.html (Accessed 10 March 2003).

Management Recommendations / Control Strategies: include references for existing site-specific strategies
"Recommendations: Because zebra mussel distribution is expanding in North America, its affects on industrial and municipal water systems will have an increasing impact. Monitoring the mussel's spread and initiating measures to mitigate and control mussel populations where they already occur are necessary to prevent serious macrofouling problems. Preventing the establishment of mussel populations in raw water systems is preferable, because subsequent removal can be both difficult and expensive.

Where encrusting population already exist, methods being used or tested to clean structures, include water jetting in larger diameter piping (Glover, 1988), abrasive blast cleaning (Daily, 1988), dewatering for up to 7-14 days (ventilating with heated air <35 degrees centigrade can greatly reduce the dewatering time require to kill mussels)(Alyakrinskaya, 1978), chemical cleaning with acids (Casey, 1988), biocides such as chlorination, bromination and ozonation (Jenner, 1983; Greenshields and Ridley, 1957; Fellers et al., 1988; Le Page, 1989), and nonoxidizing molluscicides (detoxification of discharge waters is recommended if high concentrations are used)(Lyons, 1989; McMahon et al., 1989). Methods to prevent or reduce settlement of post-veligers include use of nontoxic antifoulant coatings (Nontoxic Foul-Release Coatings. Palo Alto, California; Electric Power Research Institute, Oct. 1989. GS-6566), electric currents, biocides, molluscicides, heat treatments. Exposure to a water temperature of 32.5°C for five hours is 100% lethal to zebra mussels." http://www.gsmfc.org/nis/nis/Dreissena_polymorpha.html (Accessed 10 March 2003).

Methods of Control: There are many methods that have been investigated to help control zebra mussels. They are listed below in no particular order. Some methods will work better than others in a particular situation.

Chemical Molluscicides: Oxidizing (chlorine, chlorine dioxide) and Non-oxidizing, Manual Removal (pigging, high pressure wash), Dewatering/Desiccation (freezing, heated air), Thermal (steam injection, hot water > 32 oC*),* Acoustical Vibration, Electrical Current , Filters, Screens , Coatings: Toxic (copper, zinc) and Non-toxic (silicone-based), Toxic Constructed Piping (copper, brass, galvanized metals), CO2 Injection, Ultraviolet Light, Anoxia/Hypoxia, Flushing, Biological (predators, parasites, diseases). http://nas.er.usgs.gov/zebra.mussel/docs/sp_account.html (Accessed 10 March 2003).

Agencies Collecting Data:
The Nature Conservancy

References (includes journals, agency/university reports, and internet links):

1. GSMFC - http://www.gsmfc.org/nis/nis/Dreissena_polymorpha.html
2. ISSG - http://www.issg.org/database/species/ecology.asp?si=50&fr=1&sts=
3. USGS - http://nas.er.usgs.gov/zebra.mussel/docs/sp_account.html
4. NBII – http://www.invasivespecies.gov/profiles/zebramussel.shtml

Available Mapping Information:
http://geography.uoregon.edu/courses/geog143s02/images/invasions/zebra.gif